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SEASONAL AND DIURNAL DEPENDENCES OF Pc3 AND Pc4 GEOMAGNETIC PULSATION POWER AT VERY HIGH LATITUDES

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Introduction

In our studies [*Chugunova et al.,* 2002,03,04] we found the occurrence of ULF waves in the nominal Pc3-4 band in the polar cap. About 15% of this ULF activity is constituted by quasi-monochromatic waves. Though the mechanism of these waves in the region with open field lines has not been found yet [e.g., *Pilipenko et al.*, 2004], in this study we try to examine statistically the seasonal and yearly variations of signals and noise in the Pc3 and Pc4 range. The data of observations in Antarctica have been used, where there is practically no industrial electromagnetic interference.

Data Analysis

We used the search-coil magnetometer data from the station P5 deep in the polar cap ($\Phi = -87.6°$) during 5 years period (1996-2000). The selection of waves and their discrimination from noise have been done using the method based on identification of spectral bumps above a smoothed background level [*Chugunova et al.,* 2006]. The calculated database comprises $\sim 6 \cdot 10^4$ samples of identified waves, and $\sim 2.1 \cdot 10^5$ noise intervals. Using this database we have estimated for both H and D components the hourly energies of waves W_{Pc3} and noise R_{Pc3} in the Pc3 band (19-60 mHz) and similar parameters W_{Pc4} and R_{Pc4} in the Pc4 band (10-19 mHz).

Seasonal variations of waves and noise in the Pc3 and Pc4 bands

Figure 1 shows 2D day-hour distributions with respect to year day (Y axis) and MLT hour (X axis) of hourly energy of Pc3 waves W_{Pc3} (left-hand panel) and noise R_{Pc3} (right-hand panel) of H component. These distributions have been averaged over a 5 days period, normalized, and presented in units of standard deviation σ. The 5-year statistics confirms the result of *Chugunova et al.* [2002,03,04] about the occurrence of Pc3 wave power maximum in H component in the early morning hours (02-08 MLT) in the polar cap. The Pc3 noise has a wider maximum, comprising early morning and daytime hours, 02-14 MLT. During polar winter (days 150-270) the Pc3 wave intensity drops significantly. The noise energy also decreases during polar winter, but not so significantly as waves.

Figure 2 shows 2D seasonal-daily distribution of the wave and noise powers in the Pc4 band estimated in a way similar to Pc3. The wave spectral power W_{Pc4} has the near-noon maximum from 08 to 15 MLT, related to the cusp proximity. Similar to polar Pc3 waves, W_{Pc4} has an additional early-morning maximum from 02 to 08 MLT. The noise power R_{Pc4} is maximal in a wide MLT range, from 02 to 14 MLT. The wave and noise activity in the Pc4 band are high from spring till end of autumn, and fade away in polar winter.

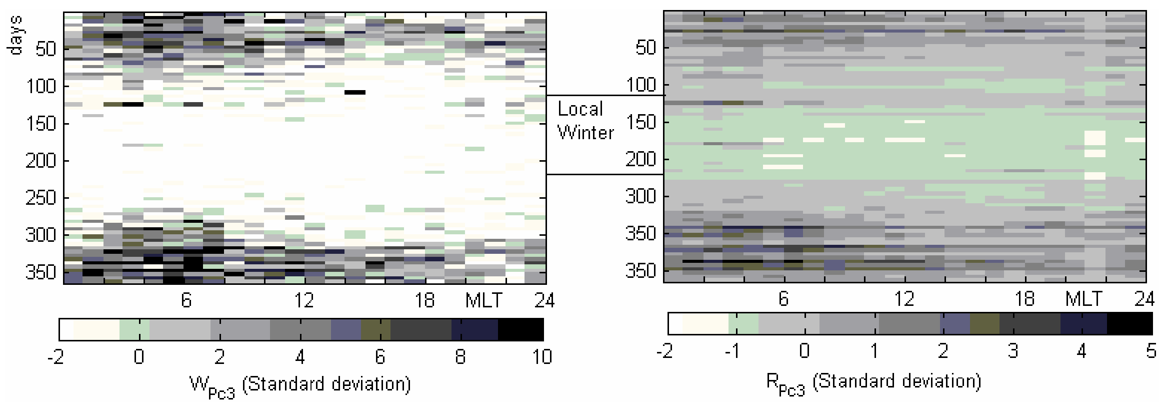

Figure 1. Day-hour distributions in respect to year day (Y axis) and MLT hour (X axis) of hourly energy of Pc3 waves W_{Pc3} (left-hand panel) and noise R_{Pc3} (right-hand panel) of H component.

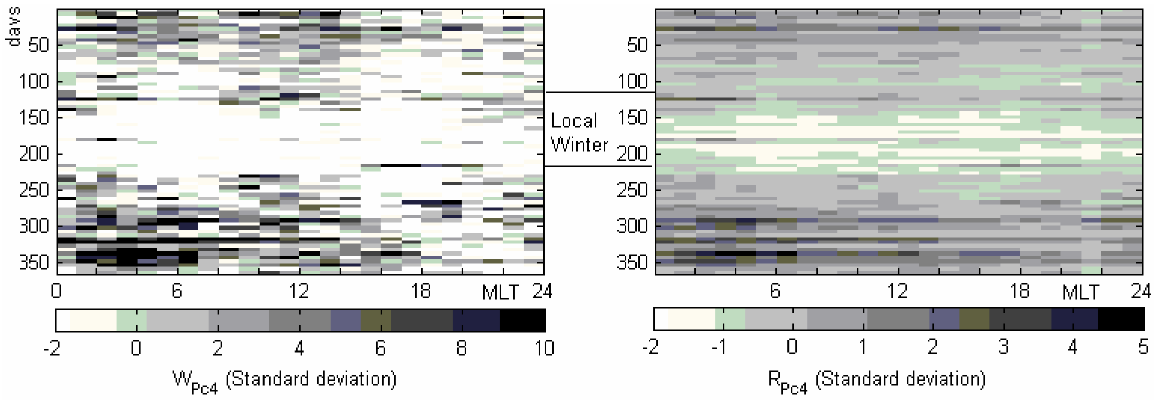

Figure 2. Day-hour distributions in respect to year day (Y axis) and MLT hour (X axis) of hourly energy of Pc4 waves W_{Pc4} (left-hand panel) and noise R_{Pc4} (right-hand panel) of H component.

Seasonal variations of Pc3/ Pc4 power and ionospheric conductance in the polar cap

Seasonal variations of ULF power may be related to variations of ionospheric conductance. To verify this juncture we have calculated throughout a year the height-integrated Hall Σ_H (thick line) and Pedersen Σ_P (thin line) conductance of the ionosphere above the polar station P5 using the empirical ionospheric model IRI-90 (Fig. 3, left-hand panel). According to this model, the ratio of ionospheric Pedersen and Hall conductance during polar day (January) and polar night (July) are 34.5 and 30.2, respectively. The same figure shows the seasonal variations of daily averaged values W_{Pc3} (middle panel) and W_{Pc4} (right-hand panel), averaged over 5 years period. In general, variations of Pc3 wave energy do follow variations of the ionospheric conductance. A similar behavior can be seen for Pc3-4 noise (not shown). Variations of Pc4 power are similar to the Pc3 variations, but have substantial fluctuations throughout a year. The ratio of averaged W and R (H component) during the polar day (days 1-40) and polar night (days 180-220) is ~8.2 for Pc3 waves and ~2.8 for Pc3 noise. For Pc4 band this ratio for waves and noise is nearly the same, ~2.3. For two cusp-latitude stations, P4 ($\Phi = -80.0°$) and P6 ($\Phi = -84.9°$), the ratio between midday (12 MLT) Pc3 wave power during polar summer and polar winter averaged over the same days is ~ 4.1 and ~3.8, respectively (not shown). The changes of relevant summer and winter ionospheric Hall conductance at these stations are 54.5 and 10.6, respectively. However, at cusp latitudes variations of conductance due to solar illumination is essentially masked by particle precipitation ionization, not taken into account by IRI model.

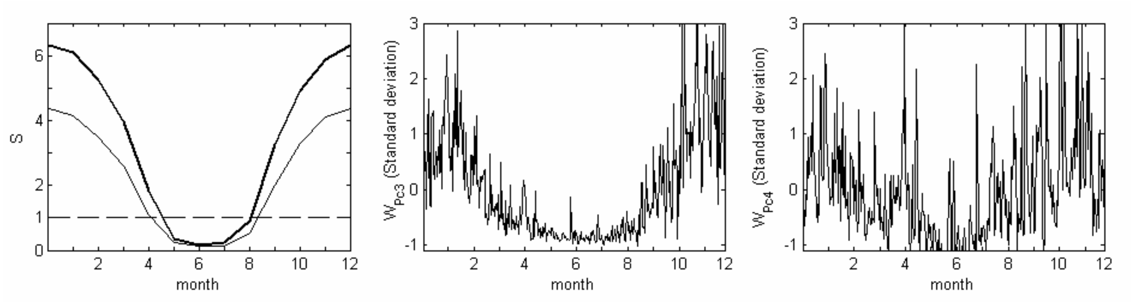

Figure 3. The height-integrated Hall (thick line) and Pedersen (thin line) conductance of the ionosphere above the polar station P5 (left-hand panel) and the seasonal variations of daily averaged values W_{Pc3} (middle panel) and W_{Pc4} (right-hand panel)

Thus, the seasonal effect of Pc3 pulsations at very high latitudes is more pronounced for waves, than for noise. In the Pc4 band the seasonal effect is weaker than in Pc3 band and the same for both wave and noise components. At cusp latitudes the contrast between the summer and winter wave powers are weaker than in the polar cap.

Let us estimate quantitatively the effect of the ionospheric conductance influence on ground ULF waves in the polar cap. The ionospheric conductance determines the Alfven wave transmission through the ionosphere. According to [*Pilipenko et al.,* 2000] the relationship between the total amplitude of the Alfven wave magnetic component B above the ionosphere and ground magnetic response, $B^{(g)}$, is $B^{(g)} = B(\Sigma_H / \Sigma_P)$ (the geometric factor $\exp(-kh)$ may be neglected for large-scale waves). It is more appropriate to deal with the amplitude of the incident wave $B^{(i)}$, which is related to the total amplitude as follows $B^{(i)} / B = (\Sigma_P + \Sigma_A)/2\Sigma_P$. Here Σ_A is the wave conductance of the magnetosphere, its typical value 1 S has been denoted by a horizontal dashed line in Figure 3. The relevant ground response is

$$B^{(g)} = B^{(i)} \frac{2\Sigma_H}{\Sigma_P + \Sigma_A} \qquad (1)$$

For a highly conductive sunlit ionosphere ($\Sigma_{H,}\Sigma_P >> \Sigma_A$) from (1) it follows

$$B^{(g)} \cong B^{(i)} \frac{2\Sigma_H}{\Sigma_P} \sim B^{(i)} \qquad (2)$$

For a low conductive dark ionosphere ($\Sigma_{H,}\Sigma_P << \Sigma_A$) from (1) one gets

$$B^{(g)} \cong B^{(i)} \frac{2\Sigma_H}{\Sigma_A} << B^{(i)} \qquad (3)$$

Comparison of relationships (2) and (3) shows that the ground response to the same incident Alfven wave under sunlit ionosphere during polar day (2) should be much higher than during polar night (3).

Conclusion

The 5 year averaged seasonal and diurnal variations of the hourly ULF powers and background noise at Antarctic station P5 deep in the polar cap have turned out to be different for Pc3 and Pc4 frequency ranges. Two maxima of Pc4 pulsations and background noise have been revealed: at near-noon hours, corresponding to the cusp activity, and in the early morning hours. For Pc3 pulsations only the early morning maximum has been detected. This morning maximum, possibly, corresponds to the geomagnetic projection of the mantle or lobe flanks. The Pc3 pulsation power has been found to be strongly dependent on the season: the power ratio between polar summer and winter seasons is about 8, whereas for Pc4 pulsations and background noise this ratio is about 3. The effect of substantial decrease of Pc3 wave amplitude during polar night is reasonably well interpreted by features of incident Alfven wave transmission through the ionosphere.

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